

2002P13061WO  
PCT/DE 03/03221

DESCPAM

EP03769222.5-PCT-  
DE 03 03221

Figure 11 shows a section through a turbine stator blade with measurement elements according to the invention,

5 Figure 12 shows a section through the turbine illustrated in Figure 10, along a line XII-XII, and

Figure 13 shows a further refinement of a measurement element according to the invention.

10 Figure 1 shows a side view of a measurement element 1 according to the invention with a plug connector 15, which is fitted to one end of the measurement element 1, for connection of the measurement element to an evaluation unit, which is not illustrated in any more  
15 detail. The measurement element 1 is designed to be elastic in the form of a rod so that the geometric shape can be matched to the predetermined requirements. Figure 2 shows a first refinement of the measurement element 1 according to the invention with two heating  
20 elements 5 between which a glass fiber (4) is arranged centrally. The arrangement is embedded in a ceramic material 16, which is itself surrounded by a passivating sheath 8.

25 Figure 13 shows a schematic view of the measurement element 2, in which the two heating wires 5 are connected in series to one another via an electrical connection 28 at one end of the measurement element 1. In this refinement, contact can thus advantageously be  
30 made completely with the measurement element 1 at one end. The second end is freely available thus allowing particularly simple installation and/or handling of the measurement element 1. A number of measurement points are indicated in the measurement element 1, and are  
35 each in the form of a fiber Bragg grating sensor. A fiber Bragg grating sensor allows a measurement

variable, in this case a temperature and thus indirectly the flow rate, to be determined very well by optical means.

- 5 Figure 3 shows a further refinement of a measurement element 2 according to the invention with a glass fiber 4 which is surrounded by a ceramic material 16. A heating element 6 completely

heating element, so that the measurement element has heat applied to it uniformly over its longitudinal extent.

5 Figure 5 shows an outline circuit diagram for a measurement configuration 18 according to the invention. A measurement element 1 is connected at each of its ends, with its heating element 6, to an electrical power source 21 via a circuit 19, a  
10 switching element 24 and an ammeter 20. In this refinement, the electrical power source 21 is a current source via which a constant direct current can be preset. Furthermore, the glass fiber 4 of the measurement element 1 is connected via an optical  
15 connecting fiber 25 to an evaluation unit 23. A fluid flow 22 flows around the measurement element 1 and has a different flow rate along the longitudinal extent of the measurement element 1, indicated by the arrows of different length. According to the invention, the  
20 evaluation unit determines the flow rate of the fluid by injecting a laser pulse into the glass fiber 4 of the measurement element 1 via the optical connecting fiber 25. The measurement makes use of the effect that an electromagnetic wave which is injected into a glass  
25 fiber is scattered by the fiber as it passes through. Some of the scattered light is scattered in the opposite direction, so that it can be detected at the input of the glass fiber. The electromagnetic wave that is scattered back is preferably detected at a time at  
30 which no electromagnetic wave is being injected into the glass fiber. The temperature of the glass fiber can be deduced from the temperature dependency of this effect. The signal that is scattered back comprises various components of different suitability for the  
35 measurement requirements. For example, the signal that is scattered back contains a Raman-scattered component,

which, however, allows only a poor spatial resolution to be achieved. The fiber Bragg grating technology is thus used in the present case, which allows high spatial resolution to be achieved as is required in particular for use for temperature measurement in machines.

The laser pulse for this purpose is produced in a known manner using equipment from the prior art. The measurement element 1 assumes a local temperature as a function of the local flow rate 22. A portion of the  
5 laser pulse is scattered back into the glass fiber 4, depending on the temperature. This signal that is scattered back is supplied via the optical connecting fiber 25 to the evaluation unit 23 which uses it to determine the temperature distribution along the  
10 measurement element , with the flow rate of the fluid being determined from the temperature distribution.

When the switch 24 is open, it is possible to use this apparatus to determine the temperature of the fluid  
15 flow 22 along the measurement element 1. The switching element 24 is then closed, and heat is applied to the measurement element 12. The flow rate of the fluid along the measurement element 1 is now determined by means of the new measurement. In order to improve the  
20 measurement accuracy, the current produced by the electrical power source 21 can be varied. The measurement can thus be repeated with different heat loads, with the flow rate being deduced from the differences. The switch may be either a mechanical  
25 switch or else an electronic switch, such as those known in a wide number of types and forms from the prior art. However, the switch may also be formed integrally with the power source 21, in which case it is possible to provide not only a switching function  
30 but also a control function for the current.

Figures 6 to 8 show position/temperature diagrams, with the temperature profile illustrated in Figure 6 along the longitudinal extent of the measurement element 1,  
35 2, 3 being that for a homogeneous flow with no heat applied. In contrast, Figure 7 shows a profile like

2002P13061WO  
PCT/DE 03/03221

DESCPAMD

EP03769222.5-PCT-  
DE 03 03221

that in Figure 6, but with heat additionally being applied to the measurement element 1, 2, 3. Figure 8 shows a temperature distribution on the measurement element 1, 2, 3, which

Patent Claims

1. A measurement element (1, 2, 3) for determination of  
a flow rate of a fluid which is flowing around the  
5 measurement element (1, 2, 3) in a flow channel (13),  
by means of an optical waveguide (4) for carrying an  
electromagnetic wave along its longitudinal extent and  
at least one electrical heating element (5, 6), which  
is arranged adjacent to the optical waveguide (4) and  
10 by means of which heat can be applied to the optical  
waveguide (4), wherein the optical waveguide (4) has at  
least two fiber Bragg grating sensors, and an  
electromagnetic wave which can be injected into the  
optical waveguide (4) can be influenced as a function  
15 of the temperature of the optical waveguide (4) at the  
location of the fiber Bragg grating sensors, which is  
dependent on the flow rate of the fluid.

2. The measurement element as claimed in claim 1,  
20 characterized in that the measurement element (1, 2, 3)  
is in the form of a rod.

3. The measurement element as claimed in claim 1 or 2,  
characterized in that the measurement element (1, 2, 3)  
25 is elastic.

4. The measurement element as claimed in one of claims  
1 to 3, characterized in that the heating element (5,  
6) is formed from metal.

30 5. The measurement element as claimed in one of claims  
1 to 4, characterized in that the heating element (5,  
6) is formed by an electrically conductive coating on  
the optical waveguide.

35 6. The measurement element as claimed in one of claims

2002P13061WO  
PCT/DE 03/03221

DE0303221

1 to 5, characterized in that the heating element (5, 6) has a constant electrical resistance per unit length.



7. The measurement element as claimed in claim 6,  
characterized in that the resistance per unit length is  
largely independent of the temperature in the operating  
5 temperature range.

8. The measurement element as claimed in one of claims  
4 to 7, characterized in that the heating element is  
formed by a heating conductor in the form of a heating  
10 loop.

9. The measurement element as claimed in one of claims  
1 to 5, characterized by a sheath (8).

15 10. The measurement element as claimed in claim 9,  
characterized in that the sheath (8) is composed of a  
ceramic material.

11. The measurement element as claimed in claim 9,  
20 characterized in that the sheath (8) is composed of  
metal.

12. The measurement element as claimed in claim 11,  
characterized in that the sheath (6) at the same time  
25 forms the heating element.

13. A method for determination of a flow rate of a  
fluid in a flow channel (13) by means of a measurement  
element (1, 2, 3) around which the fluid flows, as  
30 claimed in one of the preceding claims, with an  
electromagnetic wave being injected into an optical  
waveguide (4), which carries the wave, of the  
measurement element (1, 2, 3), with the electromagnetic  
wave being influenced by the optical waveguide (4),  
35 which comprises at least two fiber Bragg gratings, as a  
function of its local temperature at the location of

the flow rate of the fluid, with the influence of the  
electromagnetic wave being determined, and with the  
flow rate of the fluid the fiber Bragg grating sensors,  
which corresponds to along the longitudinal extent of  
5 the measurements (1, 2, 3) being determined from this.

14. The method as claimed in claim 13, characterized in that the electromagnetic wave is formed by an electromagnetic pulse.

5 15. The method as claimed in claim 13 or 14, characterized in that the measurement element (1, 2, 3) is heated in its longitudinal extent by a heating element (5, 6) during the measurement.

10 16. The method as claimed in one of claims 13 to 15, characterized in that a constant electric current is applied to the heating element (5, 6).

15 17. The method as claimed in one of claims 13 to 16, characterized in that two or more measurements are carried out with a different amount of heat applied.

20 18. The method as claimed in claim 17, characterized in that the flow rate of the fluid along the longitudinal extent of the measurement element (1, 2, 3) is determined from the difference between at least two measurements with a different amount of heat applied.

25 19. The method as claimed in one of claims 13 to 18, characterized in that a gas flow of a gas turbine (9) is used as the fluid.

30 20. A continuous flow machine (9) having rotor blades (11) which are arranged on a rotor shaft (10) which is mounted in a housing such that it can rotate, and having stator blades (12) which are arranged such that they are rotationally fixed, characterized by a measurement element (1, 2, 3) which is arranged in a flow channel (13) in the continuous flow machine (9),  
35 as claimed in one of claims 1 to 12, for measurement of a fluid flow rate.

21. The continuous flow machine as claimed in claim 20,  
characterized in that the measurement element (1, 2, 3)  
is arranged radially

5

with respect to an axis (14) of the rotor shaft (10) in the flow channel (13).

- 5 22. The continuous flow machine as claimed in claim 20 or 21, characterized in that the measurement element (1, 2, 3) is arranged coaxially with respect to the axis (14) of the rotor shaft (10) along a circular line in the flow channel (13).
- 10 23. The continuous flow machine as claimed in one of claims 20 to 22, characterized in that two or more measurement elements (1, 2, 3) are arranged axially spaced apart in the flow channel (13).
- 15 24. The continuous flow machine as claimed in one of claims 20 to 23, characterized in that the flow rate of the fluid can be determined using a method as claimed in one of claims 13 to 19.

1/3

